Evidence for the Higgs boson decay to a bottom quark-antiquark pair

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Introduction

- The Higgs discovery was made using bosonic decay channels. It is important to establish the Higgs in fermionic decay channels as well to **measure directly the Yukawa couplings**.
- In the SM, a Higgs boson with mass 125 GeV decays to bottom quarks with the **largest BR: 58%**.
- Measuring H→b$\bar{b}$ very difficult at LHC due to overwhelming multi-jet background.

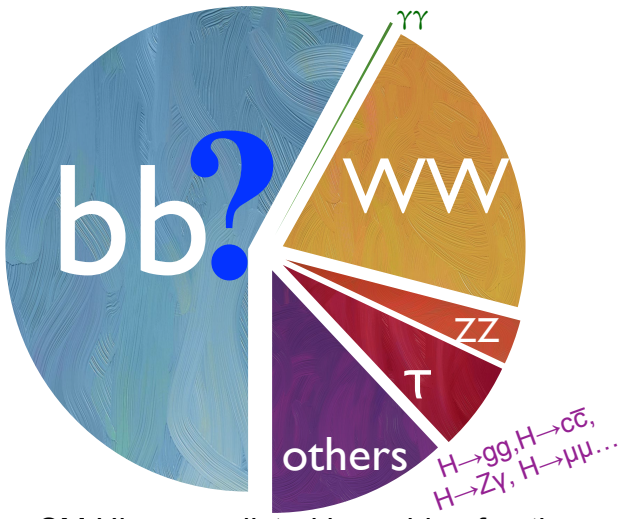
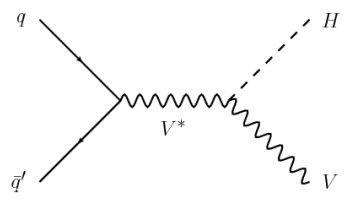


Figure: SM Higgs predicted branching fractions

VH Analysis Strategy



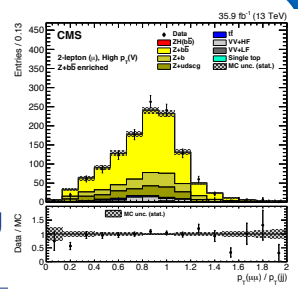
Requiring the presence of a vector boson **highly suppresses the QCD multi-jet background**, while also providing an **efficient trigger path** when it decays leptonically.

The Higgs candidate is required to be boosted ($p_T(H) > 100$ GeV), which has several advantages:

1. Reduces large backgrounds from W and Z production in association with jets and top quark production.
2. Makes accessible the Z(vv)H channel via large missing transverse energy.
3. Improves mass resolution of the Higgs candidates.

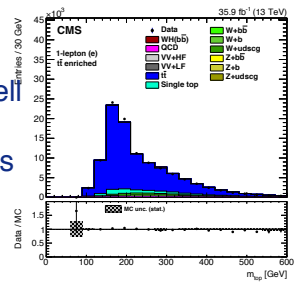
Z(ll)H(b$\bar{b}$)

Cleanest channel due to the requirement of two electrons or two muons in the final state. Lower statistics due to relatively low Z→l^+l^- branching fraction.



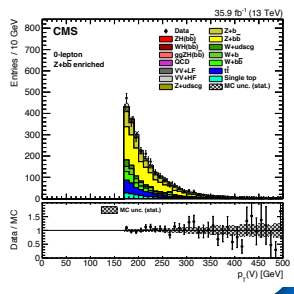
W(lν)H(b$\bar{b}$)

Requires exactly one electron or muon in the final state as well as missing transverse energy. Large background contributions from top production and W production in association with jets.



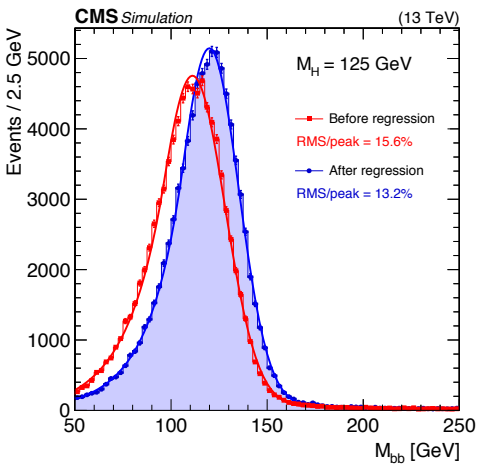
Z(νν)H(b$\bar{b}$)

Since there are no leptons in the final state, triggers are used which require large online missing transverse energy. Additional requirements are made to reduce the small remaining QCD multi-jet contribution.



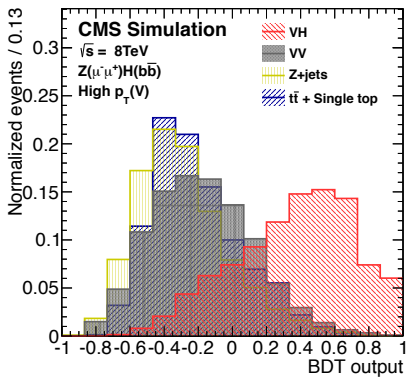
b-jet Energy Regression

- The b-jet energy resolution and response are worse than for light quarks due to neutrinos.
- A regression is trained targeting the generator-level jet p_T and applied to candidate b-jets.
- The regression **improves the di-jet mass resolution by ~10%** and corrects the peak position.



BDT

A Boosted Decision Tree (BDT) is trained separately for each decay channel on a set of input variables to discriminate background from a combination of VH(b$\bar{b}$) and ggZH(b$\bar{b}$) signal. A maximum likelihood fit is performed on the BDT output to extract the observed signal contribution.



Results

After taking into account all systematic uncertainties, the fitted signal strength relative to the Standard Model expectation for M_H = 125 GeV is $\mu_{13TeV}=1.19^{+0.21}_{-0.20}(stat)^{+0.34}_{-0.32}(syst)$ with a significance of **3.3 standard deviations**. When combined with the 8 TeV measurement the fitted signal strength is $\mu_{8TeV+13TeV}=1.06^{+0.31}_{-0.29}$ with a significance of **3.8 standard deviations**.

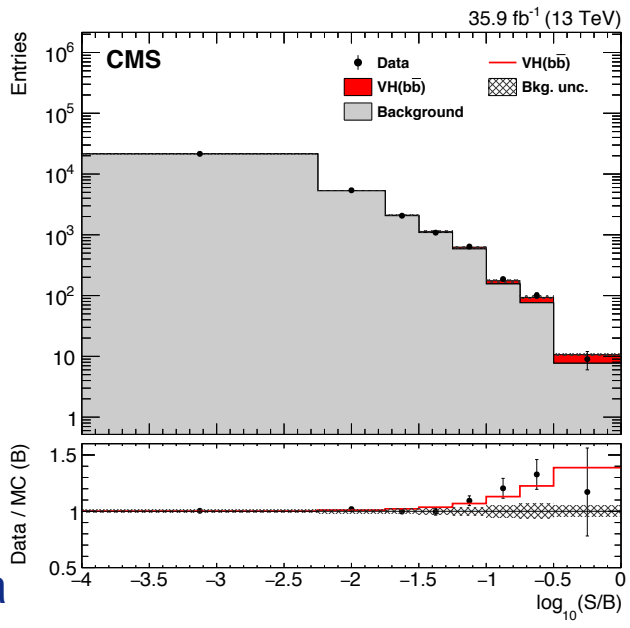


Figure: Combination of all VH(b$\bar{b}$) channels into a single distribution. Events are sorted in bins of similar expected signal-to-background ratio, as given by the value of the output of their corresponding BDT discriminant.

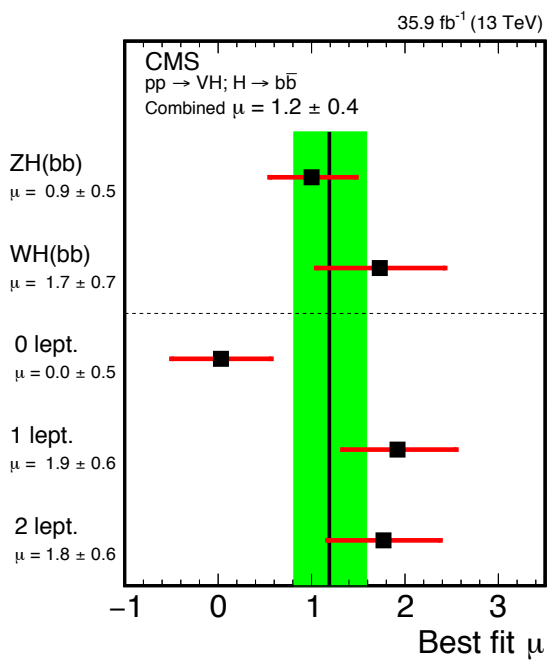


Figure: The best fit value of the signal strength $\mu = (\sigma \times BR) / (\sigma \times BR)_{SM}$, at m_H = 125.09 GeV, is shown in black with a green uncertainty band. Also shown are the results of a separate fit where each channel is assigned an independent signal strength parameter.

References

1. *Evidence for the Higgs boson decay to a bottom quark-antiquark pair.* ***arXiv:1709.07497.*** *Submitted to Phys. Lett. B.*
2. *Search for the standard model Higgs boson produced in association with a W or a Z boson and decaying to bottom quarks. CMS PAS HIG-13-012.* ***PhysRev.D.89 012003***